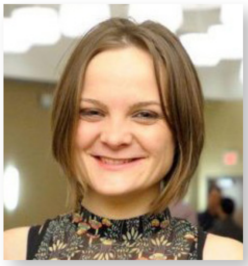
BU Global Development Policy Center

GEGI WORKING PAPER 058 • 12/2022

Triangle of Economic Activity, Inequality and Green Transition in South Africa

OZLEM OMER AND JERONIM CAPALDO



Özlem Ömer *is a Non-Resident Research Fellow with the Global Economic Governance Initiative at the Boston University Global Development Policy Center. She was an assistant professor at NEVÜ in Turkey. Her research interests include growth and inequality, distributive impacts of economic policies, forces and dynamics of structural change, and financial crises, among others. She holds an MS in Economic Policy from University of Illinois at Urbana-Champaign and a PhD from the New School for Social Research.*

ABSTRACT

In this paper, we introduce an extended version of a demand-driven growth and climate model which was initially developed by Omer and Capaldo (2022). The model is modified to include the size distribution of two different households (the bottom 90 percent of the households versus top 10 percent of the households) with different consumption behaviors. In this version, we are also able to trace the external debt and emissions under different scenarios in more detail. Overall, these modifications allow us to study the dynamics of economic activity, fiscal and monetary policies and debt, and their relationships with income and emission inequality patterns under different climate pathways and with different policy options for South Africa. We, therefore, analyze and discuss potential tradeoffs that may arise between expansionary policy, stricter policy and free riding cases, focusing on economic activity, external debt and income and emission inequalities in South Africa.

INTRODUCTION

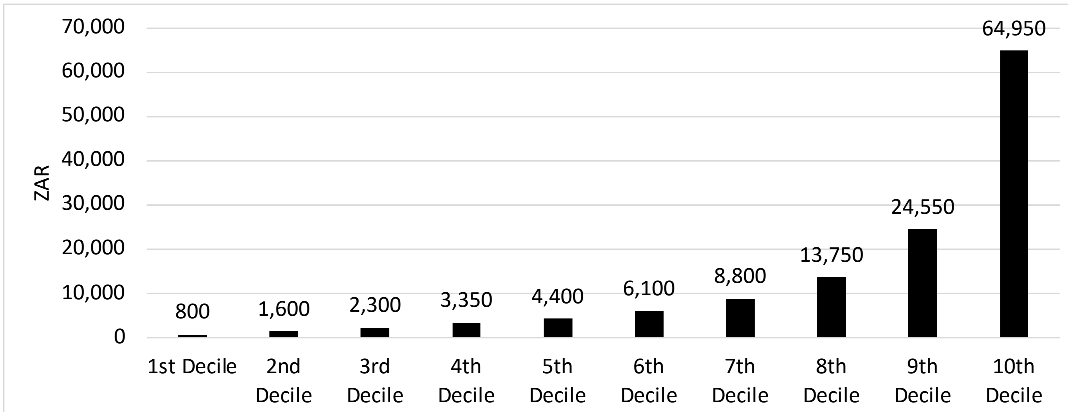
South Africa is one of the most unequal countries in the world. According to the World Bank (2022), wage differences within and between households are the main contributor of income inequality (66 percent), followed by business (11 percent) and other incomes (13 percent). As Figure 1 shows, in 2017, the bottom 60 percent of households in South Africa earned less than R 6,600 per month. The main source of household income was social grants and government transfers. They were mostly employed in low paying agriculture and service sectors. According to the most recent World Bank

__Jeronim Capaldo__ is a Non-Resident Senior Research Scholar with the Global Economic Governance Initiative at the Boston University Global Development Policy Center. He researches globalization, trade and labor market policies and is an expert on global macroeconomic models. He has worked as development economist in Food and Agriculture Organization, International Labour Organization and United Nations Department of Economic and Social Affairs and is currently an Economic Affairs Officer in the Division on Globalization and Development Strategies at the UN Conference on Trade and Development, where he contributes to the annual Trade and Development Report.

Report (2022), in 2017, poor and vulnerable households were made up of black Africans (90 percent) and Asian Indians and people of color (10 percent). Middle class households (61 percent to 90 percent) were at the core of the formal working class and earned between R 6,600-R26,000 per month. They were mostly employed in heavy industry, mining, education and other skilled service sectors (Makgetla, 2020). Their main source of income was wages and salaries. Most Black Africans fall within the first eight deciles; however, the share of Black African households in the middle class recovered from 45 percent to 60 percent between 2008 and 2017.

The richest 10 percent of households earned as high as R 65,000 per month (Finn et. al., 2009; World Bank, 2022). Most of them were employed as managers and high-level professionals. Their main source of income was capital income—mostly due to business ownership (ibid).

Figure 1: Median Monthly Household Income per income group, 2017



Source: Makgetla, N., 2020. Inequality in South Africa: An Overview, TiPS.

Wealth inequality is even higher than income inequality in South Africa. According to the World Bank (2022), the richest 10 percent – mostly white households – own 72 percent of total wealth. The middle class and bottom 60 percent of the households own only 22.5 percent and 5.5 percent, respectively. Overall, race and gender seem to play a major and increasing role in income and wealth inequality—41 percent of inequality was caused by racial discrimination (World Bank, 2022).

Why do we observe this extreme distortion within the size distribution? When we take a closer look at inequality, there is a strong relationship between the size distribution and sectoral inequality. As discussed by Omer and Capaldo (2022), the link between the productive structure of the economy (i.e., sectoral productivity, employment, wage differentials and the movements of labor between the stagnant and productive sectors) and domestic as well as international policies shape the dynamics of growth and inequality. This, in turn, determines how resilient or vulnerable the economy is in case of an extreme event, such as the COVID-19 pandemic or climate-related disasters.

The events of the last three years have shown how fragile the global economy is and provide meaningful indications on what to expect from the next shock: how severe the outcomes will be, and which economic actors will be most affected. Indeed, each shock is followed by similar, although not identical, developments. The COVID-19 crisis is the most recent and unique example to which policymakers should pay close attention to prepare for the future climate-related crises because these might share some of the strongest economic outcomes observed before, during and after the peak of the pandemic. The main difference may be that climate crises will have more persistent, heavier and less remediable consequences.

Matching current inequality patterns in South Africa with sectoral inequality can shed some light on determining which income groups are or will be most affected in case of a catastrophic event. To do this, we focus on the changes in the sectoral structure in South Africa in three periods: before the COVID-19 pandemic, early pandemic and late pandemic. As Table 1 shows,[1] comparing the long-term averages (1990-2016) with the averages in 2018, productivity in agriculture and mining slightly increased while other sectors experienced a decline.

Table 1: Monthly Earnings and Productivity Before, During and After the Peak of the COVID-19 Pandemic

EARNINGS vs. PRODUCTIVITY		PRODUCTIVITY GROWTH (%)		PRODUCTIVITY LEVELS per employee/per month (ZAR)		MONTHLY REAL EARNINGS including overtime & bonuses per employee (ZAR)			
Sectors		AVG (1990-2016)	AVG (1990-2018)	AVG (2016)	AVG (2018)	AVG (2016, Jun)	AVG (2019, May)	AVG (2020, May)	AVG (2021, May)
DYNAMIC	Agriculture	2.13	2.50	2,178	2,491	-	-	-	-
	Mining	3.44	3.49	50,645	54,917	18,084	22,446	21,289	23,849
	Manufacturing	1.70	1.45	24,570	23,655	13,114	16,784	14,876	16,807
	Utilities	3.71	2.77	77,331	62,836	29,403	38,828	39,318	40,396
	Trade services	1.68	1.44	14,558	14,083	9,932	12,738	11,050	12,488
	Transport & storage	2.27	1.91	30,179	28,507	17,969	22,802	20,483	22,334
STAGNANT	Community, social and personal service (Government & Business Services)	-0.48	-0.54	16,105	16,105	18,122	22,665	24,065	24,305
	FIRE	-0.15	-0.15	117,112	102,834	15,636	21,461	21,186	21,423
	Construction	0.79	0.59	8,705	8,705	10,886	14,957	13,046	15,456
	Private Household	-	-	-	-	-	-	-	-
	Other	1.10	0.66	8,458	8,298	-	-	-	-
	ECONOMY-WIDE AVG.					***18,723***	***22,429***	***23,084***	***23,982***

Source: Groningen Growth and Development Center, 10-Sector Database for South Africa, https://www.rug.nl/ggdc/structuralchange/previous-sector-database/; Stats SA. (2018,2019,2020,2021). *Quarterly Employment Statistics*. Pretoria: Stats SA.

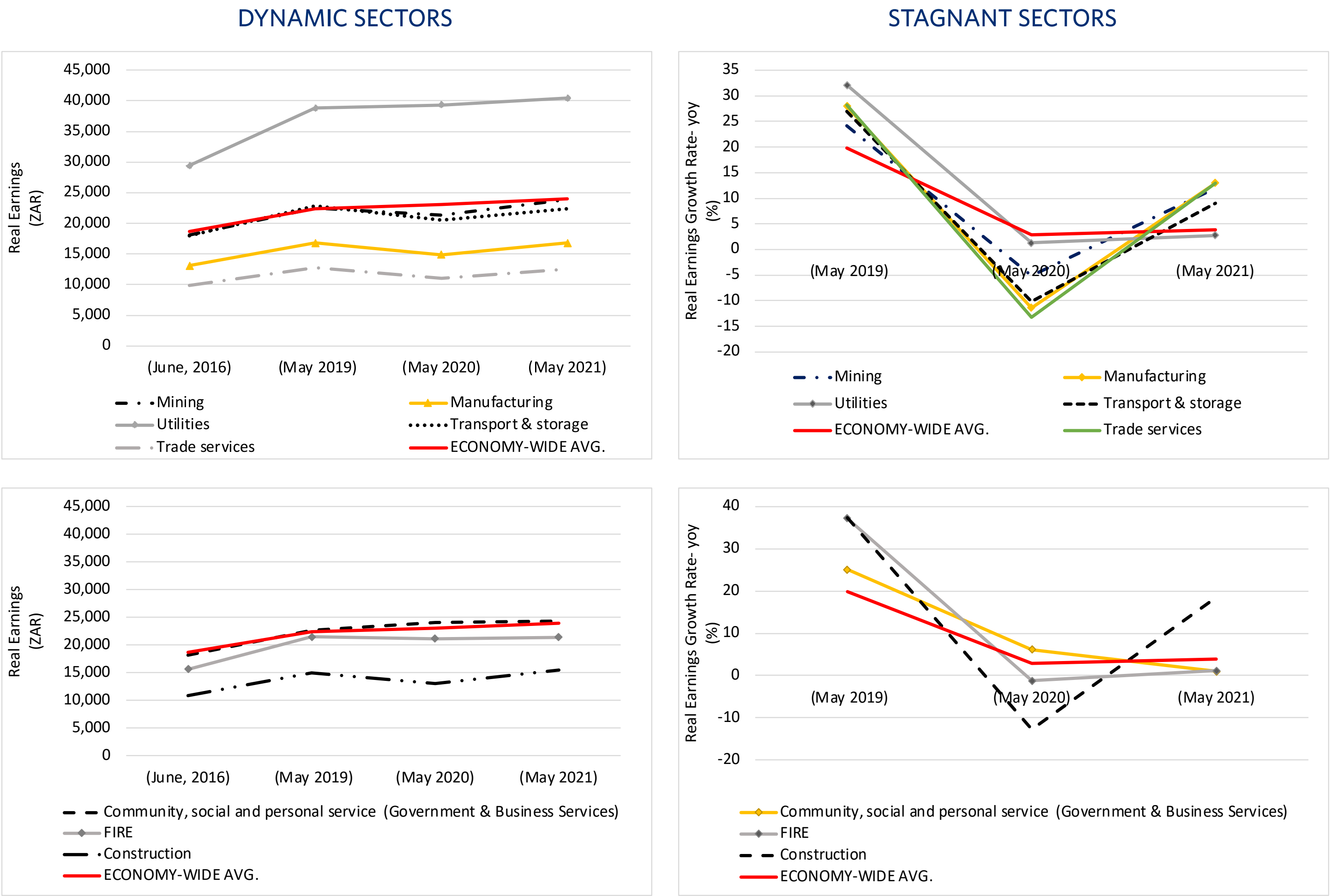
As Figure 2 illustrates, **before the pandemic** (2016-2019), real monthly earnings increased in every sector, but the largest jump occurred in Finance and Real Estate (FIRE) (37 percent), construction (37 percent) and utilities (32 percent). In 2019, the highest paying sectors were utilities, transportation and storage, government and business services, mining, and FIRE while trade services, construction and manufacturing paid the lowest, below economy-wide average.

At the peak of the pandemic, the most vulnerable sectors were manufacturing, transportation and storage, trade services, and construction. Their monthly earnings diminished by 11 to 13 percent from their pre-pandemic levels. However, **after the peak of the pandemic**, these recovered faster than the rest, although their earnings stayed below the economy-wide average in 2021. On the other hand, the growth rate of real monthly earnings in utilities, FIRE, government and business sectors stagnated but remained positive.

According to Ranchod and Raynolds (2021), women were about 10 percentage points more likely to lose their jobs than men during the COVID-19 Pandemic. Following Table 2, gender inequality is apparent economy wide. Women's employment shares in each sector (except community, social and personal services) range between 11 percent and 41 percent and have been declining throughout the pandemic. Gender inequality is even stronger in the highest paying, male-dominated sectors. For example, women's share in Utilities—the highest paying sector – dropped by 5 percentage points from its already low, pre-COVID-19 level (30 percent) to 25 percent in late 2021 (post-peak-COVID-19), which means that women were replaced by men, signaling a deterioration in income

[1] For more details see Omer and Capaldo (2022) and Taylor and Omer (2019, 2020).

Figure 2: Sectoral Real Monthly Earnings vs. Economy-wide Average Monthly Earnings



Source: Stats SA. (2018, 2019, 2020, 2021). *Quarterly Labour Force Survey*. Pretoria: Stats SA.; Stats SA. (2018, 2019, 2020, 2021). *Quarterly Employment Statistics*. Pretoria: Stats SA.

Table 2: Employment Share of Men vs. Women, 2021

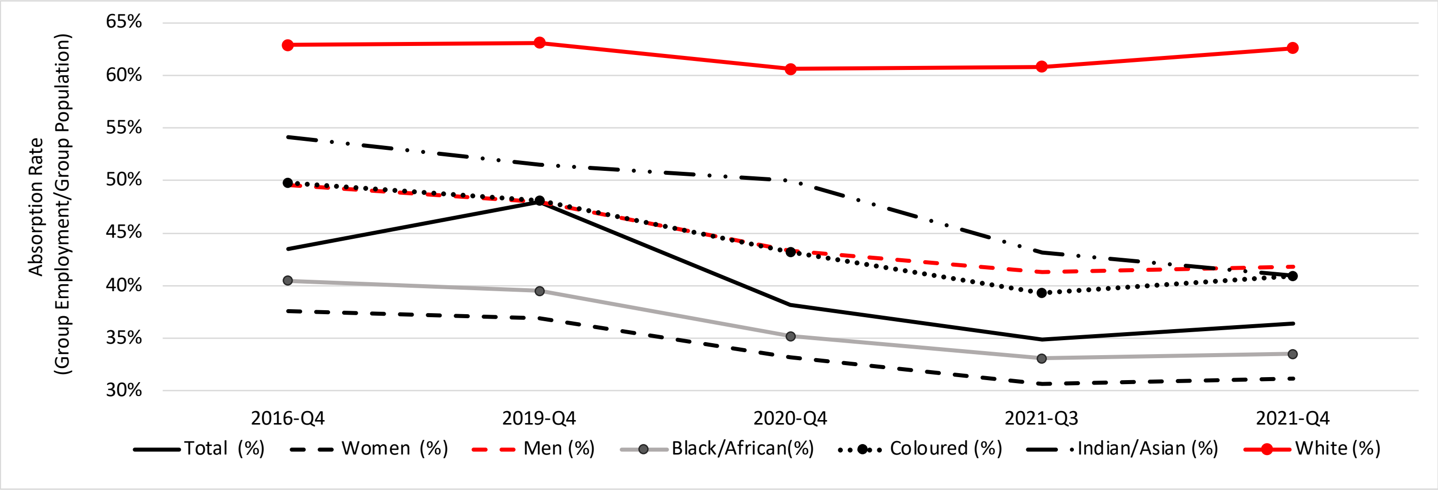
	Sectors	SECTORAL WOMEN' EMPLOYMENT SHARE (Within Sector)				SECTORAL-MEN' EMPLOYMENT SHARE (Within Sector)			
		2016	2019 (Pre-Covid)	2020 (Peak)	2021 (Post-Peak)	2016	2019 (Pre-Covid)	2020 (Peak)	2021 (Post-Peak)
DYNAMIC	Agriculture	33.2%	34.1%	28.7%	26.8%	66.8%	65.9%	69.3%	73%
	Mining	14.7%	16.5%	13.0%	11.9%	85.3%	83.3%	83.3%	88%
	Manufacturing	32.1%	35.2%	34.1%	32.7%	67.9%	64.8%	64.6%	67%
	Utilities	28.0%	30.0%	29.2%	25.0%	72.0%	70.0%	67.7%	75%
	Wholesale and Retail	48.2%	45.6%	44.6%	43.8%	51.8%	54.4%	54.6%	56%
	Transport & storage	19.7%	19.2%	16.3%	17.1%	80.3%	80.9%	80.7%	83%
STAGNANT	Community, social and personal service (Government and Business Services)	61.2%	61.7%	61.3%	61.6%	38.8%	38.3%	38.7%	38%
	FIRE	41.6%	41.6%	40.8%	41.4%	58.4%	58.4%	59.2%	58%
	Construction	11.7%	10.7%	11.2%	13.0%	88.3%	89.3%	88.8%	86%
	Private Household	76.6%	75.5%	74.2%	76.4%	23.4%	24.5%	25.8%	26%
	Other	-	77.8%	77.8%	-	-	22.2%	22.2%	-

Source: Stats SA. (2018,2019,2020,2021). *Quarterly Labour Force Survey*. Pretoria: Stats SA.; Stats SA. (2018, 2019, 2020, 2021). *Quarterly Employment Statistics*. Pretoria: Stats SA.

and gender inequality. Other higher paying, male-dominated sectors, such as transportation and storage, mining and FIRE also follow the same pattern. Construction, one of the lowest paying sectors, is the only sector where women's share recovered in the late-pandemic period.

Another way to look at inequality in South Africa is via racial stratification. Black Africans have the largest share of overall population (around 80 percent) followed by white (9.2 percent), Coloured[2] Africans (8.9 percent) and Indian-Asians (2.5 percent). Therefore, it's no surprise that Black Africans hold the largest number of jobs. However, when we look at each group's *employment-population rate* in Figure 3, the employment rates of Black Africans and women have been the lowest (40 percent and 37 percent, respectively), declining throughout the pandemic. Both groups experienced losses of 7 to 8 points in their employment-population ratios with little to no recovery of late. In contrast, approximately 65 percent of white Africans have been employed and were least affected by the pandemic. Overall, whites are twice as likely to be employed compared to other racial groups.

Figure 3: Employment-Population Rate By Group (Absorption Rate)



Source: Stats SA. (2018,2019,2020,2021). *Quarterly Labour Force Survey*. Pretoria: Stats SA.; Stats SA. (2018,2019,2020,2021). *Quarterly Employment Statistics*. Pretoria: Stats SA.

As mentioned, a household's position in the size distribution of income and workers' sector of employment have played major roles in determining the fallout of the pandemic. Schotte et. al (2022) argue that "job losses" are the main cause of the transition to poverty for one-third of households in South Africa, pointing out the importance of labor market dynamics. According to the same study, approximately 40 percent of population is permanently poor— 94 percent of them are Black, 67 percent are women and none of them are white. Meanwhile, 14.7 percent of the population is "never poor" – 93.6 percent of them are white. Moreover, 7.8 percent of women are never poor while the ratio is 34.8 percent for men (Schotte et. al 2022).

Climate-driven economic downturns will be most damaging to the most vulnerable members of the population—Black people and women who are mostly employed in low-paying sectors with low productivity growth. Therefore, climate policies, which should focus on transforming the productive, sectoral structure of the economy, must also eliminate existing inequalities to prevent future struggles that the bottom 90 percent of households may face—60 percent of whom are chronically poor, Black and/or women, unemployed or employed in informal sectors.

[2] The term is used in South Africa's official statistics.

In the following sections, we introduce an extended version of a demand-driven growth model which was initially developed by Omer and Capaldo (2022). The model is modified to include the size distribution of two different households (the bottom 90 percent of the households versus the top 10 percent of the households) with different consumption behaviors. In this version, we are also able to trace the external debt and emissions under different scenarios in more detail. Overall, these modifications allow us to study the dynamics of economic activity, fiscal and monetary policies and debt, and their relationships with income and emission inequality patterns under different climate pathways and with different policy options for South Africa.

A DEMAND-DRIVEN GROWTH MODEL WITH CLIMATE CHANGE AND INEQUALITY

In this section, we introduce a demand driven growth and climate model with two household classes. Our focus is on the impacts of climate change, fiscal and monetary policies on economic activity, especially on the distribution of income and emissions between wage earners (representing the bottom 60 percent of the households) and profit earners (representing the richest top 10 percent of the households).

As introduced and explained in detail by Omer and Capaldo (2022), in this model, income distribution (via profit share), labor productivity, capital accumulation and accumulation of greenhouse gases (GHG) determine aggregate demand, which in turn determines the level of economic activity. Therefore, we can trace the short- and long-term impacts of climate change induced by increasing concentration[3] in a single-open economy, reflecting the fact that South Africa's contribution to the global emission stock is negligible (1.06 percent of the total).

In the short term, any changes which increase aggregate demand and employment will also drive-up real wages and cut into profits (a profit squeeze). Assuming, as other studies do, [4] that reduced profits have a negative impact on investments which in turn, may outweigh the positive effect of wage and employment increases on consumption (i.e., the economy is profit led) the ultimate effect on economic activity is negative. But any increase in economic activity pushes up emissions in South Africa and elsewhere. In the long run, without effective mitigation efforts, increasing atmospheric GHG accumulation pushes down profitability and causes faster capital depreciation such that investment declines and the economy stabilizes at undesirably low levels of output and investment. As shown below, this poses an existential threat to developing countries.

In this paper, we extend the existing model in order analyze the distributional dynamics—income inequality between workers and capitalists which can be interpreted as bottom 90 percent of the households versus the top 10 percent of the households, inequality of their emissions and long-term debt dynamics. Our objective is to assess the effects of fiscal and monetary policies under different climate change pathways—business-as-usual (BAU) and 425 ppmv atmospheric carbon concentration – on income distribution, emission distributions and national debt in South Africa.

Model Description

MACRO BALANCE AND SHORT RUN ECONOMIC ACTIVITY AND DISTRIBUTION

In the model, everything is in real terms, and short to medium term economic activity and distribution are represented by capacity utilization, $\boldsymbol{u[t]} = \frac{Output}{Total\ capital\ Stock} = \frac{X[t]}{K[t]}$ and profit share,

[3] This paper focuses on concentration because it has had (and will have) the largest impact on climate change.

[4] According to Onaran and Galanis (2012), South African economy is profit-led. However, if the economy is wage-led, it might cause a further increase in economic activity.

$\boldsymbol{\pi[t]} = \frac{Profits}{Output} = \frac{P[t]}{X[t]}$, respectively while long run trajectories are shaped by the dynamics of endogenous capital stock per capita $\boldsymbol{\kappa[t]} = \frac{K[t]}{Population}$, labor productivity $\boldsymbol{\xi[t]} = \frac{Output}{Labor} = \frac{X[t]}{L[t]}$ and exogenously determined global greenhouse gas GHG accumulation.

Let $\boldsymbol{X}$ be real GDP (output), $\boldsymbol{C}$ is total consumption, $\boldsymbol{I_g}$ and $\boldsymbol{I_p}$ are the investments of the government and private sector, and $\boldsymbol{G_g}$ and $\boldsymbol{M}$ are non-mitigation and mitigation expenditures on GHG mitigation efforts[5], respectively. $\boldsymbol{T}$ represents taxes, $\boldsymbol{EX}$ and $\boldsymbol{IM}$ are exports and imports, respectively. The model introduces different classes with different saving rates—s_c, as saving rate of capitalists out of capitalist household income, consisting entirely of profits, and s_w, as the saving rate of workers out of worker household income, consisting entirely of wages; therefore, total saving rate is $\frac{S[t]}{X[t]} = s[t] = s_c\,\pi[t] + (1 - \pi[t])\,s_w$, where $s_c > s_w$.[6]

As a result, the macro balance can be represented as:

$$X[t] = C[t] + I_P[t] + I_g[t] + M[t] + G_g[t] + (EX[t] - IM[t])$$

Consumption function is $C = (1 - s[t] - \tau)X[t]$ where saving ratio $s[t]$ is an increasing function of profit share ($\pi[t]$). $M[t]$ and $G_g[t]$ represent mitigation and non-mitigation expenditures of the government, respectively.

Following Kalecki (1971) and the structuralist Keynesian tradition (Taylor et.al, 2015; 2018, 2020), we assume that gross fixed capital formation (private investments), $I_P[t]$ is driven by profit rate $r[t] = \pi[t] * u[t]$, animal spirits $(g_o - g_i r)$ and economic activity $u[t]$ so that

$$I_P[t] = ((g_o - g_i r) + \alpha\pi[t]u[t] + g_u u[t])K[t]$$

where $(\boldsymbol{g_o} - \boldsymbol{g_i} r)$ represents animal spirit and takes the changes in real interest rate $\boldsymbol{r}$ into account[7]. As a result, private investment-capital stock ratio is $\frac{I_P[t]}{K[t]} = \boldsymbol{g[t]} = (g_o - g_i r) + \alpha\pi[t]u[t] + g_u u[t]$.

Government investment is proportional to capital stock accumulation, $K[t] = \kappa[t]Pop[t]$;

$$I_g[t] = \iota_g K[t]$$

Exports are assumed to be driven by an exogenous real exchange rate, z[8], and capital stock-GHG concentration ratio $(K[t]/G[t])$:

$$EX[t] = \epsilon\left(\frac{K[t]}{G[t]}\right)^f z[t]^\gamma \text{ where } f \text{ and } \gamma > 0.$$

Exports are assumed to be proportional to GHG accumulation because the impacts of climate change and /or transition to zero-carbon economy by the rest of the world will reduce the demand for South African export commodities in two ways: first through declining income of the rest of the world, and second through declining incentives of consuming fossil-fuel base South African commodities (i.e., coal and commodities that are produced using carbon-energy).

[5] All the variables are treated as "flows" per unit of time.

[6] Namely, redistribution towards capitalists which earn profit income leads to higher savings.

[7] For the purpose of assessing the monetary policies in our simulations, real interest rate r, is introduced as a jump parameter, where $\frac{\partial I}{\partial r} < 0$.

[8] Real exchange rate $z[t]$ is introduced as an exogenous variable where $\frac{z'[t]}{z[t]} = \sigma\,(1 - z[t]/2)$. It is assumed to be stable initially. In some simulations, it is allowed to depreciate or appreciate for policy purposes. An increase in $z[t]$ means depreciation of local currency—ZAR weakens.

Similarly, imports are determined by domestic income ($X[t]$) and the changes in real exchange rate ($z[t]$). Any increase in domestic income pushes up demand for imports while the depreciation of real exchange rate, represented as an increase in $z[t]$ pushes it down.

$$IM[t] = a\frac{X[t]}{z[t]^c} \text{ where } a = \ import\ ratio\ and\ c > 0.$$

Mitigation expenditures ($\boldsymbol{M[t]} = \boldsymbol{m\,X[t]}$) and the leakages i.e., taxes, savings and imports are set proportional to output while the injections (i.e., exports, investments and non-mitigation government spending) are proportional to capital stock ($K[t]$). Therefore, macro balance becomes:

$$X[t] = (1 - s[t] - \tau)X[t] + (g_o + \alpha\pi[t]u[t] + g_u u[t])\,K[t] + \iota_g K[t] + (\beta\,K[t] + mX[t]) + \epsilon\left(\frac{K[t]}{G[t]}\right)^f z[t]^\gamma - a\,z[t]^{-c}\,X[t]$$

As mentioned earlier, profit share represents short to medium term distributional dynamics. In the model, capitalist savings and investments are positively related to profit share (profit-led economy). If the increase in investments is strong enough, output, employment and capital stock can go up. Global GHG accumulation, taken exogenous,[9] also affects the profits by reducing profitability and investment demand. If global emissions can be reduced by higher global mitigation efforts, the system may stabilize at a lower GHG concentration—our simulations will be set to produce different paths for different potential GHG concentration scenarios that in turn have exogenous effects on South African economy via profits, capital accumulation and exports.

In the labor market, when the employment is higher (and the labor market is tighter) due to increasing economic activity, profit share will tend to decline such that increased economic activity will be partially offset by profit-squeeze (à la Marx and Goodwin). In the meantime, labor productivity may rise with a higher level of investment[10] and lower employment while higher GHG concentration can reduce the productivity. Overtime, capital accumulation will be driven by investments as the size of the economy expands.

In the model, any increase in GHG accumulation has an impact on profit share through a damage function, affecting profitability. Overall, profit share is represented as a function of GHG concentration ($G[t]$) via damage function $Z[G]$ and employment-population ratio, $\lambda = \frac{\kappa\,u}{\xi}$, such that

$$\pi_{[t]} = f(G, \lambda) = f\left(Z(G), \frac{\kappa\,u}{\xi}\right) = \frac{(\phi\,Z[t])^A}{\lambda[t]^B}$$

where κ is capital stock per capita, u is capacity utilization and ξ is labor productivity.

A, B > 0, $\eta = 0.5$ so the damage function, $Z[t]$ is

$$Z[t] = \left(1 - \left(\frac{G[t] - G_{(Preindustrial)}}{G_{Max} - G_{(Preindustrial)}}\right)^{\frac{1}{\eta}}\right)^{\eta}$$

9 It is exogenous because South Africa plays a negligible role in affecting the atmospheric GHG concentration. Therefore, GHG accumulation is set as a "shift" variable using an exogenous dynamic equation to represent potential global responses to climate change and their impacts on South African economy. On the contrary, it is an endogenous state variable in the original "global climate" model, where its dynamics are driven by global emissions, natural abatement rate, mitigation rate, energy intensity and energy productivity.

10 It can also increase as a result of an increase in energy intensity (energy/labor ratio) but they are not included explicitly in this version of the model. See Rezai et al. (2018) for the "global" version of the model.

$G[Preindustrial]$ represents the preindustrial level of atmospheric CO_2 concentration, which is equal to 280 ppmv (parts per million per volume) while G_{Max} is 780 ppmv. As mentioned above GHG accumulation and tighter labor market cut into profit share (profit-squeeze) so that partial derivatives of both G and λ are negative $\left(\frac{\partial f}{\partial G} \text{ and } \frac{\partial f}{\partial \lambda} < 0\right)$.

LONG RUN EQUATIONS

Our first endogenous, dynamic "state variable" represents the dynamics of the capital stock per capita $\kappa[t]$, hence growth rate of capital stock per capita $\hat{\kappa}[t]$ is

$$\frac{\dot{\kappa}[t]}{\kappa[t]} = (g[t] + \iota_g) - \delta_0 - Pop[t] - \delta_1 G[t]$$

where $g[t] = \frac{I[t]}{K[t]} = ((g_o - g_i r) + \alpha\pi[t]u[t] + g_u u[t])$, $g_i * r$ represents the impact of real interest rate on real investments and initially set to be constant[11], δ_0 is capital stock depreciation, δ_1 is the depreciation caused by GHG accumulation $G[t]$, and $Pop[t]$ is population growth rate[12], and ι_g is government investment-capital stock ratio. GHG accumulation ($G[t]$) has a direct impact on capital stock through increasing depreciation. As a result, capital stock per capita is determined by capital accumulation, population growth and the depreciation caused by the global GHG accumulation.

Our second long run equation is labor productivity growth, represented as "a technical progress function" (Kaldor 1957; 1978). It shows that faster output growth and/or higher investments result in increasing returns to scale with decreasing cost and leads to use of more advanced technologies. Therefore, growth rate of labor productivity is

$$\hat{\xi}[t] = \frac{\dot{\xi}[t]}{\xi[t]} = \gamma_0 + \gamma_1\hat{\kappa}[t] - \gamma_2(\lambda[t] - \bar{\lambda})$$

where employment -population ratio equals to $\lambda[t] = \frac{\kappa[t]u[t]}{\xi[t]}$. $\gamma_0 > 0$ is the exogenous rate of productivity growth, $\gamma_1 > 0$ represents the capital deepening affect caused by capital accumulation, and γ_2 captures the labor market dynamics—tighter labor market (lower unemployment) has a negative effect on productivity growth. Increased GHG accumulation could also diminish productivity indirectly via its effect on capital stock accumulation ($\hat{\kappa}[t]$).

An "exogenous" GHG accumulation equation, representing the changes in atmospheric CO_2 concentration is introduced in order to trace potential future climate change dynamics, and their impacts on South African economy. $G[t]$ is **exogenously** set to generate different global climate scenarios i.e., Global and South African Business as Usual scenario, which CO_2 concentration reaches to catastrophic levels (780 ppmv) in the long term, and a global mitigation scenario which leads to a lower CO_2 concentration level i.e., 425 ppmv.

$$\hat{G}[t] = \frac{\dot{G}[t]}{G[t]} = a\left(1 - \frac{G[t]}{\bar{G}}\right) - \frac{\Omega(1 - e^{-\varphi t})}{\varphi}.$$

[11] It will be used as a jump variable to implement expansionary vs. contractionary monetary policy impacts in different scenarios.

[12] An exogenous dynamic equation is introduced to determine the long-term population dynamics.

Additionally, we introduced a DEBT accumulation function—$\widehat{D}[t]$, which is determined by the dynamics between total net lending/net borrowing, and total capital stock, working as a scale of the system. This way, we will be able to analyze the long-term behavior of debt dynamics in the economy, therefore;

$$\widehat{Debt}[t] = \frac{\dot{Debt}[t]}{Debt[t]} = \frac{\left[(I_P[t] - S_c[t] - S_w[t]) + \left(I_g[t] - S_g[t]\right) - S_f[t]\right]}{K[t]}.$$

$(\boldsymbol{I_P[t] - S_c[t] - S_w[t]})$ is private sector's net lending/borrowing; $\left(\boldsymbol{I_g[t] - S_g[t]}\right)$ is government's net lending borrowing; $\boldsymbol{S_f[t] = IM[t] - EX[t] + int_0\ Debt[t]}$ is the rest of the world's net lending/borrowing (or their savings), and $\boldsymbol{int_0\ Debt[t]}$ total **net** interest payments on debt. As a result, if ***Total Investment*** > (***Total Savings*** + ***Net Debt Payments***) national debt increases.

Finally, assuming South African population will reach to 100 million and stabilize in the long run, population growth is represented by an exogenous dynamic equation, $\frac{\dot{Pop}[t]}{Pop[t]} = n\left(1 - \frac{Pop[t]}{100}\right)$. When we look at the distributional data for South Africa, we see that the number of households in the capitalist class (top 10 percent of the households) has not been changing; therefore, we assume that population growth increases the size of the bottom 90 percent of the households, while the size of the capitalist class stays the same[13].

Extension of the Model

WORKERS VS. CAPITALIST

Consumption, $C[t]$ is divided between workers $C_w[t]$ and capitalists $C_c[t]$, therefore; total consumption after tax and savings is

$$C[t] = C_w[t] + C_c[t]$$

$$C_w[t] = X[t] * (1 - \pi[t])\,(1 - \tau_w)(1 - s_w) - (\theta_w * int_o\ Debt[t]) + (int_1 * S_w[t]) + c_w$$

where τ_w is the tax rate of workers—workers' taxes = $T_w[t] = X[t] * (1 - \pi[t])\,\tau_w$; s_w is the saving propensity of workers and proportional to wages, $\boldsymbol{S_w[t]}$ is the savings of workers—they still save a small but positive amount out of their wages, and $\boldsymbol{int_1}$ is the interest on their savings; hence $(int_1 * S_w[t])$ represents the wealth effect on their consumption while $(\boldsymbol{\theta_w * int_0 * Debt[t]})$ represents their share in net interest payments on their debt; $\boldsymbol{c_w}$ is the constant coefficient of consumption[14]. Overall, their main income is the wages, and they assume to consume all of it after taxes, and savings. Workers' saving equation, therefore is

$$S_w[t] = s_w\,(1 - \pi[t])X[t]$$

Following the uses of income accounting, their disposable income is

$$DYH_w = C_w[t] + S_w[t].$$

---

[13] This assumption allows us to calculate disposable income per-capitas of different households so that we can also calculate the Palma ratios of different income classes, which sheds light on the dynamics of income inequality.

[14] Interests on total debt are assumed to be paid only by the government and the capitalist class; hence, based on external debt data of private and government in South Africa, initial debt shares are $\theta_w = 0, \theta_c = 0.37$ and the government's share is $(1 - \theta_c - \theta_w)$ = 0.63.

Capitalist consumption is

$$C_c[t] = X[t]\,\pi[t]\,(1-\tau_c)\;(1-s_c) + (int_1 * S_c[t]) - (\theta_c * int_o\, Debt[t]) + c_c.$$

where $\boldsymbol{\tau_c}$ is the tax rate of capitalists—Capitalists' taxes= $T_c[t] = X[t]\,\pi[t]\,\tau_c$; is the saving rate of capitalists and proportional to profits, $\boldsymbol{S_c[t]}$ is the savings of capitalists—they are the main source of savings, and $\boldsymbol{int_1}$ is the interest on their savings; hence $\boldsymbol{(int_1 * S_c[t])}$ represents positive wealth effect on their consumption while $\boldsymbol{(\theta_c * int_0 * Debt[t])}$ represents their share in net interest payments of their debt; $\boldsymbol{c_c}$ is the constant coefficient of their consumption. Overall, their main source of income is capital income. Capitalists' saving and disposable income equations are:

$$S_c[t] = s_c\,\pi[t]\,X[t]$$

$$DYH_c[t] = C_c[t] + S_c[t]$$

Based on this income disaggregation, we can calculate the Palma Ratio as—the ratio of average disposable income of con to average disposable income of capitalists

$$Palma_{DYH}[t] = \frac{\left(\frac{DYH_c[t]}{Pop_c[t]}\right)}{\left(\frac{DYH_w[t]}{Pop_w[t]}\right)}.$$

GOVERNMENT

Government expenditure (mitigation and non-mitigation spending):

$$M[t] + G_g[t] = m\,X[t] + \beta\,K[t] - ((1-\theta_c-\theta_w) * int_0 * Debt[t])$$

where $(1-\theta_c-\theta_w) * int_0 * Debt[t]$ represents net interest payments on its debt.

Government Investment (spending):

$$I_g[t] = \iota_g\,K[t].$$

Government income (total taxes on workers and capitalists):

$$T[t] = (\pi[t] * X[t] * \tau_c) + (1-\pi[t]) * X[t] * \tau_w.$$

As a result, its saving (Fiscal Balance) becomes

$$S_g[t] = T[t] - \big(M[t] + G_g[t]\big).$$

Closing the model, the rest of the world's (ROW) saving equation is:

$$S_f = IM[t] - EX[t] + int_0\,Debt[t]$$

SIMULATIONS

Simulation Scenarios

This section compares the economic impact of the BAU climate scenario with two mitigation policy scenarios and a free-riding scenario—under 425 ppmv pathway. In BAU (red line), the atmospheric CO_2 concentration is assumed to stabilize at around 780 ppmv in the long run with catastrophic outcomes, as the temperature will jump well above 3°C. In the mitigation scenarios, atmospheric CO_2 concentration stabilizes around 425 ppmv[15] such that the global temperature remains between 1.5°C-2°C above pre-industrial levels. Under 425 ppmv pathway, the *gray line* represents "stricter" fiscal and monetary-mitigation policies in South Africa; the *green line* represents the "free riding" case, where only the rest of the world mitigates while South Africa free-rides. The *blue-dashed line* represents "expansionary" fiscal and monetary-mitigation policies. In the mitigations scenarios under 425 ppmv pathway (blue-dashed and gray lines) in which mitigation policies are adopted worldwide, South Africa adopts two different fiscal and monetary policy packages to support its mitigation and adaptation efforts—every financial (and investment) decision is assumed to take the green transition into account.

EXPANSIONARY POLICY SCENARIO (BLUE-DASHED LINE)

Expansionary policies are key to preventing secular stagnation in developed and developing countries if they crowd-in productive investment and are supported by progressive taxation and/or government transfer policies (Taylor et. al, 2015; Omer and Capaldo, 2022). That is because productive investment increases the productive capacity of the economy, creating extra income while progressive taxation and transfer policies redistribute it to lower income classes, limiting increases in profits (or capitalist income). Therefore, **in our expansionary policy scenarios (blue-dashed line)**:

- The government spends 2.5 percent of gross domestic product (GDP) per year on mitigation and adaptation.[16] Mitigation (and adaptation) spending by the government is assumed to be used only in activities related to the green transition, such as investing in green and renewable energy technologies, subsidizing green manufacturing technologies, reducing motor vehicle use, increasing energy efficiency of buildings and ending deforestation. As a result, government mitigation spending aims at increasing the productive capacity of the economy by attracting and facilitating green private investments.

As government mitigation spending can stimulate private investment, relatively lower and stable interest rates can help the process. Following Omer and Capaldo (2022),

- We, therefore, let real interest rate decline by 1.5 percentage point from its initial level—from 2.5 percent to 1 percent.

Under such circumstances, the real exchange rate will be affected by changes in real interest rates. As a result, in this scenario,

- The South African Rand (ZAR) is assumed to depreciate slowly – around 6 percent by 2100 and 15 percent in the longer term.[17]

---

[15] Atmospheric CO2 was around 400 ppmv in 2016.

[16] Mitigation and adaptation spending can be used to invest green and renewable energy technologies, subsidize green manufacturing technologies, reduce motor vehicle use, increase energy efficiency of buildings, end deforestation, etc. As explained in the model section, mitigation spending (m) is proportional to GDP—m X[t], so annual mitigation spending will vary with economic activity.

[17] It is a fact that long-lasting weakening of local currency can lead to cost driven inflation dynamics and reduce real purchasing power of workers, especially if the economy is highly depended on imported intermediates and capital. The effect

Finally, public spending on mitigation will crowd in private investment but financing remains a major concern for all developing economies. Since progressive taxation can help mobilizing private savings held by the wealthy and loosening the budgets for households with higher propensity to spend,

- Taxes on the capitalist class (the richest 10 percent of households) are increased by 20 percent while taxes on workers stays the same.

THE "STRICTER" POLICY SCENARIO (GRAY LINE)

In this policy package, the goal is to highlight the potential impacts of austerity measures that South Africa might take if fear of deficit and inflation takes hold. Therefore,

- The government is assumed to spend 1.5 percent of GDP per year on mitigation efforts (as opposed to 2.5 percent in the expansionary policy scenario).

- As in the expansionary scenario, exports will fall by 15 percent initially, as the rest of the world moves away from coal-related products. In contrast, the real interest rate is assumed to be increased by 1.5 percentage point from 2.5 percent to 4 percent due to difficulties in obtaining multilateral financing and fears of inflation. As a result, the real exchange rate is assumed to *appreciate* by 15 percent gradually.

- In order to analyze different tax policies, the taxes on **both** capitalists and workers are raised by 20 percent—as opposed to the expansionary policy scenario. The idea is to eliminate the potential problems regarding fiscal space and long-term debt burden.

FREE-RIDING BY SOUTH AFRICA SCENARIO (GREEN LINE)

Finally, in this scenario, South Africa chooses inaction which means that mitigation measures to keep atmospheric CO2 concentration around 425 ppmv, were taken *only* by the rest of the world, while South Africa continue to pollute. Therefore,

- Real interest and real exchange rates, and taxes remain unchanged.[18]

- Exports are assumed to fall more than the previous scenarios – *25 percent* as the rest of the world will move away from coal-related products[19] more drastically as policies like carbon border adjustment measures take place, so that South Africa loses its initial export share.

SIMULATION RESULTS

Economic Activity: BAU vs. Mitigation Scenarios under 425 ppmv Pathway

In the simulations, the BAU scenario (red line) demonstrates the severity of global warming and its implications for the future of the South African economy in the absence of effective global mitigation.

South Africa's economic trajectories in the BAU scenario are shown in Figure 4. Initially, the economy grows at around 2 percent per year and continues growing until 2060 when the environmental breakdown is projected to take place. Productivity also increases with increasing capital stock and economic activity, cutting into employment. This initially gives rise to a slow increase in the profit

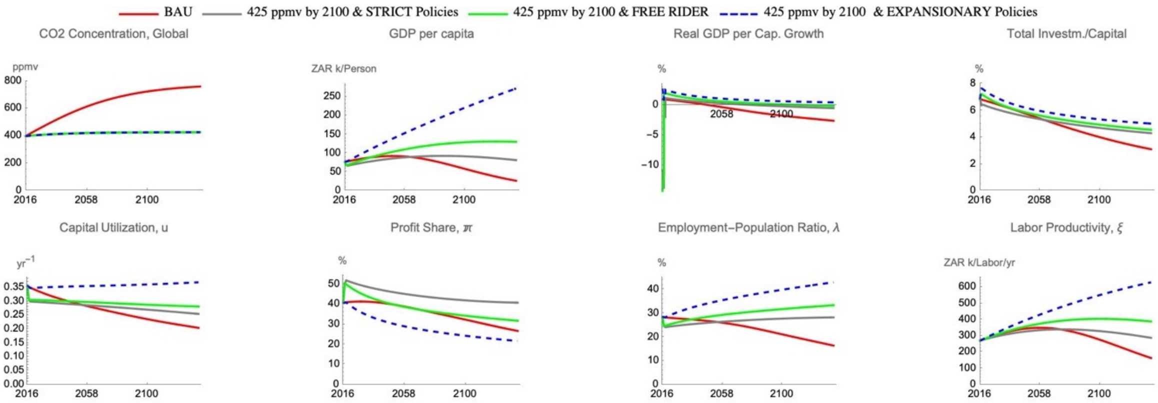
---

would be even stronger if imports exceed exports (Taylor, 1982). That is why we assumed a stable and manageable depreciation of the real exchange rate.

[18] This is an oversimplification, but we only want to focus on the best possible "free rider" scenario although it is the least possible one given South Africa's fiscal and financial fragilities along with its highly problematic productive structure.

[19] Carbon Border Adjustment Mechanism (CBAM), introduced by the EU, is an example supporting this assumption.

Figure 4: Economic Activity Under Different Scenarios



Source: Authors' calculations.

share. After a few decades, productivity and profits diminish with a sharp decline in capital accumulation when climate damage starts to cut into profitability and capital stock.

High concentration will lead to capital destruction to an extent that it will make economic recovery impossible, eventually pushing the economy into a "bad" equilibrium where output and capital per worker will be well below 2016 levels. Real output will peak around 2060 then it will begin shrinking, leading to a sharp decline in capital utilization. More than a hundred years of economic growth will be wiped out.

In the expansionary policy scenario (blue-dashed line), economic activity increases more than in other scenarios. Climate damage's effect on profits is offset via global mitigation efforts. Therefore, any decline in the profit share is caused by increasing economic activity as employment and real wages reach higher levels. As the profit share stabilizes around a lower rate (approximately 20 percent) in the long run—thanks to strong labor market dynamics and progressive taxation – profits are squeezed, real wages follow the same path as labor productivity, meaning increasing labor productivity is mostly translated into increasing real wages. Combined with increasing employment, this results in a higher wage share, reducing income inequality.

Under the "stricter" policy scenario, higher real interest rates, which leads to stronger real exchange rate, eliminate the crowding-in effect caused by government's mitigation spending, such that the investment-capital ratio declines and stabilizes at a lower rate than the expansionary policy and free riding cases. Moreover, higher taxes especially on workers' income reduce consumptions as workers have higher propensity to consume causing further declines in aggregate demand and income (Figure 4). As a result, macroeconomic tightening produces the second worse outcome.

On the other hand, economic activity in South Africa benefits more in the "free-riding" scenario than in the "stricter" policy scenario. However, free-riding cannot save South Africa from falling into a low productivity, low GDP, low employment spiral since inaction limits productive investments, especially when export-led recovery is not possible due to a coal-dependent tradable-goods sector.

Overall, *in the BAU scenario*, inaction proves catastrophic, pushing South Africa into a depression. Free riding and stricter policies will lead to long run stagnation, although free riding creates better outcomes than the stricter policy case. Expansionary policies together with progressive taxation can support green-structural change with sustainable and equitable growth.

COMPONENTS OF BALANCE OF PAYMENTS AND DEBT DYNAMICS

In this section, our focus is to assess the impacts of the above policy scenarios. The macro balance for an open economy can be simply represented as

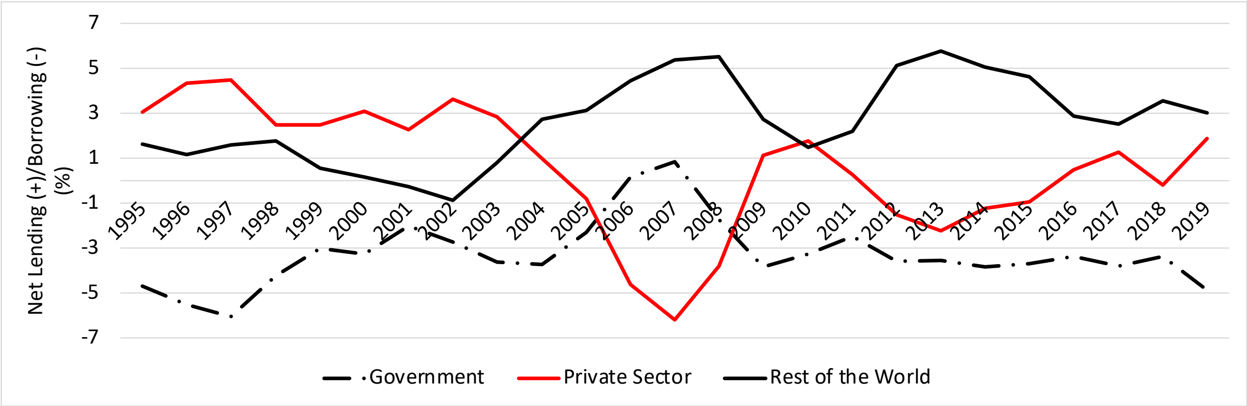
$$(S_p - I_p) + (S_g - I_g) + (IM - EX) = 0$$

$$S_g = (Taxes - Government\ Spending - Government's\ Mitigation\ Spending)$$
$$= (T - G_g - M)$$

where private savings and investments are S_p and I_p, S_g and I_g are government's saving and investment, while IM and EX are imports and exports—$(IM - EX)$ represents the savings of the rest of the world. In other words, $(S_p - I_p)$, $(S_g - I_g)$ and $(IM - EX)$ are private sector's, government's, and ROW's net borrowing (lending), respectively— if they are smaller (larger) than zero—$(IM - EX)$ also represents current account balance. Based on the macro balance equation, if a country had a current account deficit $(EX < IM)$, it means that either private or public sector (or both) were the net borrower (lender) —meaning that capital inflows (outflows) must increase (decrease) to keep the balance. Overall, if countries' net total borrowing increases, net external debt rises.

Figure 5 shows that, In South Africa, between 1995 and 2019, on average, the private sector (households and businesses) and the external sector were net lenders, meaning $(S_p - I_p) > 0$ and $(IM - EX) > 0$. In 2016—initial year in our simulations, South Africa had a current account deficit $(IM - EX)$ = approx. -3 percent of GDP), private sector was the net lender $(S_p - I_p)$ = approximately +0.43 percent of GDP) while the government sector was the net borrower (approximately -3.5 percent of GDP). As a result, South Africa was a net borrower—total net borrowing was approximately 3 percent of GDP in 2016.

Figure 5: Net Lending (+)/Borrowing (-)



Source: FRED, data on South Africa's Net Lending.

As Figure 6 shows, in the BAU case, the current account deficit worsens until 2060 as increased economic activity pushes up the demand for imports. But once economic activity starts to decline, the current account balance recovers as the demand for imports also declines. The fiscal balance deteriorates since tax revenues cannot catch up with government spending. Declining economic activity cuts into tax revenues, while an increased fiscal deficit pushes the government to borrow more. As a result, rising government borrowing and interest payments on existing debt drive the debt-to-GDP ratio up to unsustainable levels. On the other hand, as private investment declines faster than private saving, the private sector improves its position as a net lender. However, this does not prevent domestic net borrowing from reaching unsustainably high levels. Inaction translates into a high debtor position in South Africa after 2060, with a default projected to take place well before 2100.

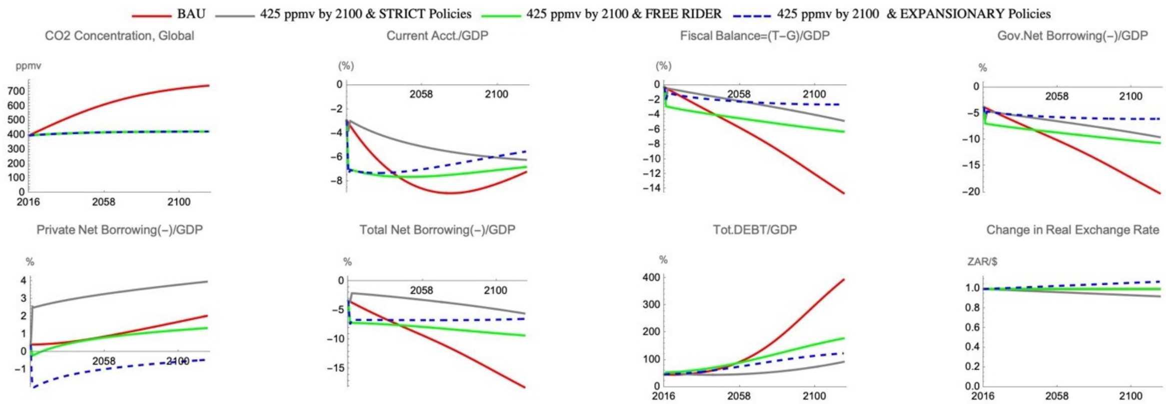
In the stricter policy scenario, slower GDP growth suppresses the positive effects of the real exchange rate appreciation on imports and limits the demand for imported goods and services. Exports also decline due to exchange rate appreciation; however, the reduction in imports is stronger, leading to a better current account position in the short and medium run. In the very short run, aggressive tax increases for both capitalists and workers improve the fiscal balance, reducing the government's need for borrowing. Yet, in the longer term, both the fiscal deficit and government borrowing deteriorate as weak economic activity, caused by stricter policies fails to generate enough tax revenue. As in the BAU scenario, private investment declines more than private savings, improving the private sector's net position. Yet, this time the reason is not climate change but interest rate hikes that discourage investment. This brings about lower capital stock accumulation (lower investment), lower labor productivity and stagnant economic growth. Overall, total domestic net borrowing follows a lower trajectory than in other cases. This, in turn, lowers the debt-to-GDP ratio in the medium term but the tradeoff is costly: an economic structure with low productivity, low growth and higher inequality. Therefore, the debt-to-GDP ratio increases from around 50 percent to 90 percent in the long term. Overall, the long-term macroeconomic behavior of the system under the stricter policy case raises questions about the long-term sustainability of debt.

In the free riding case, the current account deficit declines sharply as a result of an initial negative shock to exports, then remains stable in proportion to GDP (-7 percent of GDP). Slow economic activity mostly caused by lack of investment and low taxes compared to other cases results in fiscal deficit and total net borrowing that are larger but stable, leading to a better outcome in terms of debt-to GDP ratio compared to the BAU scenario. Under these circumstances, long term debt cannot be sustainable.

The impact of expansionary policies on fiscal balance, on net borrowing and on debt sustainability are a major concern for developing countries (and for their lenders). However, if these policies generate higher economic activity—via investment, productivity, real growth and employment channels – they can lead to sustainable and equitable growth, while supporting long-term debt sustainability. *In the expansionary policy case (blue line)*, the current account balance first deteriorates due to increased imports and the initial export shock, but it recovers later with the help of a weak real exchange rate (Figure 6). The fiscal balance and government net borrowing stabilize at much lower levels supported by higher economic activity and progressive taxation. Higher economic activity pushes up tax revenues mostly from the capitalist class (top 10 percent of households) while relatively lower tax rates on workers (bottom 90 percent) with the help of higher economic activity increase workers' consumptions more than capitalists' because workers have lower saving rates.

When we look at the borrowing behavior of the sectors, weaker interest rates and the crowding-in effect of government spending are projected to stimulate private investment, turning the private sector into a net borrower. As a result, total domestic net borrowing stabilizes at a higher rate than in the stricter policy case. This in turn, leads to a higher but stable debt-to-GDP ratio (around 100 percent of GDP). But this downside remains negligible because high economic activity supported by government spending and supportive real interest and exchange rates, creates the necessary dynamics to improve the current productive structure and equitable growth simultaneously, and eliminates the risk of unsustainable debt problems in the long term.

Figure 6: Net Borrowing (-)/Net Lending (+) and External Debt



Source: Authors' calculations.

Income Inequality: Capitalists vs. Workers

The impact of progressive taxation policies is more obvious when we look at the distributional dynamics between capitalists (top 10 percent of households) and workers (bottom 90 percent of households) in more detail. Figure 7 displays the Palma ratio of disposable income calculated as the ratio between capitalists' and workers' average disposable incomes:

$$Palma_{DYH}[t] = \frac{\left(\frac{DYH_c[t]}{Pop_c[t]}\right)}{\left(\frac{DYH_w[t]}{Pop_w[t]}\right)}$$

In 2016, the average annual disposable income of the top 10 percent of households was ten times higher than for the bottom 90 percent. Under BAU (red line), in the first few decades with the existing tax policies, disposable income grows faster for capitalists than for workers, increasing inequality – the Palma ratio goes up by 30 percent by 2060. However, after the climate crises hits around 2060, the ratio declines below pre-crisis levels as the result of sharply declining profits (capital income). Therefore, inequality declines due to increasing climate damage impact on profits.

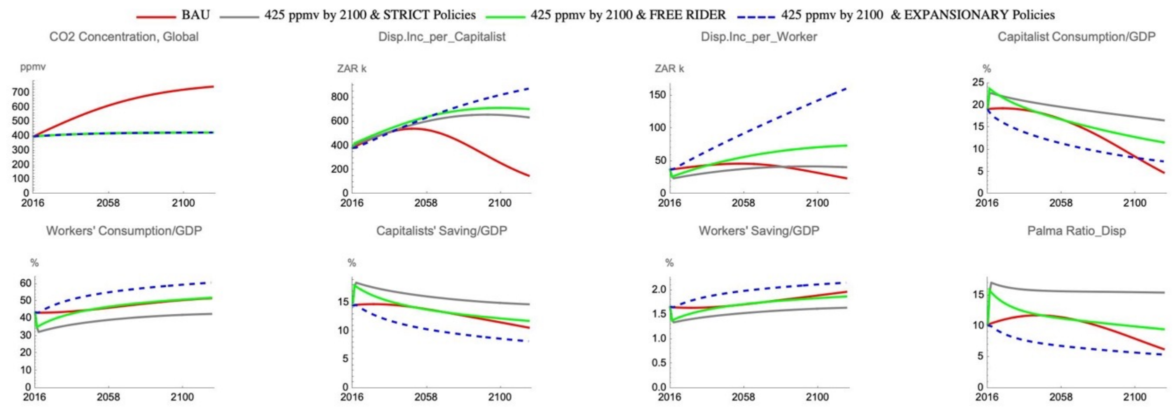
In the free riding case, a larger export shock (25 percent initially), first, pushes down capacity utilization and increases unemployment driving up the profit share. Moreover, increased mitigation by the rest of the world reduces the impacts of climate change, also contributing to profit growth. The Palma ratio goes up by 50 percent until employment begins to rise squeezing profits. Then, wages and workers' consumption go up while capitalists' income, consumption and savings decline such that the Palma ratio stabilizes at around its initial level in 2016.

In the stricter policy scenario (gray line), economic activity increases at a much slower rate than the free-riding case due to higher interest rates, appreciated exchange rates and high taxes on both capitalists and workers. On top of that, average disposable income of capitalists also rises more than the disposable income per worker. This means that any increase in real outcome, even though it is small, is transferred to profits, which is the main income source of capitalist class. Consequently, the Palma ratio goes up and stabilizes at a very high level—over 60 percent. In this case, increased taxes provided a better outcome in terms of fiscal and external balance; however, they deteriorate already high inequality with stagnating economic growth.

Finally, *in case of expansionary policies (blue line)*, with the help of progressive taxation, disposable income per worker grows faster than disposable income per capitalist. Higher taxes (20 percent increase) on capitalist income cut into their income and spending. Their savings are also affected negatively. Meanwhile, higher economic activity helps redistributing generated income towards the workers; as a result, their income and consumption go up, pushing up their savings. As a result, the Palma ratio stabilizes at a much lower level, indicating a sharp decline in income inequality.

Our results highlight the importance of redistributive policies. In addition to progressive taxation policies, government transfers and social programs can provide alternative channels to support the bottom 90 percent of the households, while decarbonizing the economy.

Figure 7: Income Inequality Under Different Scenarios



Source: Authors' calculations.

Emissions and Emission Inequality Between the Bottom 90 percent and Top 10 percent of Households

According to Ravallion et. al. (2000), there may be a trade-off between climate stabilization and equity if income is redistributed from households (or countries) with a low propensity to emit carbon dioxide to those with higher propensities: if growth is sufficiently fast and/or inequality is low enough, emissions decline because reduction of emission and inequality is positively associated with growth (Ravallion et. al., 2000).

In case of South Africa, the bottom 90 percent of households have a lower saving propensity but command fewer emissions per capita than the top 10 percent of the households. According to an OXFAM report, in 2008, average emissions were 4.35 tonnes CO2, but ranging from 2.05 to 20.3 tonnes of CO2 per capita for the bottom 90 percent and the top 10 percent of the households, respectively. Differences in consumption and emission patterns of different households urge us to introduce a metric that reveals useful information regarding emission inequality in countries that experience high income and wealth inequalities such as South Africa. This metric can be used to design distributive policies that are tied to green transformation.

As discussed by Omer and Capaldo (2022), evidence suggests that labor productivity growth is highly correlated with energy consumption[20] (Semieniuk et. al, 2021; Jiang & Khan, 2017; von Arnim, R., & Rada, C., 2011, Ravallion et al., 2000). Studies show that historically labor productivity growth has been driven by increasing amounts of carbon energy per worker[21] (the average elasticity of the carbon energy-labor ratio with respect to labor productivity is close to one, as estimated by Semieniuk, 2016). Taking these findings into account, the growth rate of energy-use per worker ($\hat{q}[t]$) is assumed to be highly correlated with the labor productivity growth. Therefore, the dynamics of energy-use per worker are captured by

$$\hat{q}[t] = v\,\hat{\xi}[t]$$

where v is the elasticity between energy use per labor and labor productivity (Rezai et al., 2018). If $v = 1$, the relationship between the labor productivity (ξ) and energy-use per worker (q) feature constant elasticity, meaning that energy per labor growth follows the exact same pattern as the labor productivity growth. Given that v was proven to be close to 1[22], in the BAU scenario we set it to be equal to 1, while in mitigation scenarios, it is set to 0, indicating that labor productivity growth is explained by energy productivity increases while energy use per labor stays constant.

In more detail[23], labor productivity is, $\xi = \frac{X}{L}$, energy use per labor is $q = \frac{E}{L}$ and energy productivity is $\epsilon = \frac{X}{E} = \frac{\xi}{q}$. As a result of this relationship, emissions are determined by the economic activity, represented by total capital stock, its energy use per unit output (inverse of energy productivity = $\frac{E}{X} = \frac{q}{\xi}$ and the carbon intensity of the energy use.[24]

Therefore, total emission growth rate is

$$\widehat{EMIS}[t] = \left(\hat{q}[t] - \hat{\xi}[t]\right) + \hat{K}[t]$$

This equation tells us that

- If the relationship between energy-use per worker and the labor productivity is constant $v = 1$, emissions increases based on capital stock accumulation.
- If ($0 \leq v < 1$) energy productivity cuts into emissions as it reduces the energy use per labor.[25]

Unless renewables replaced fossil fuels, emissions will grow at the same rate as the capital stock, given that $v = 1$—which is the case for the BAU scenario. If $v < 1$ and fossil fuels are still the main energy source, then emissions would still be growing but it would be slower than the previous case because $v < 1$ means that energy productivity is higher, cutting into the growth of the energy-worker ratio. This relationship also tells us that increasing energy productivity (where $v < 1$) in a fossil fuel dependent country such as South Africa would not be enough to reduce emissions, although it would slow down its rate of increase.

[20] Given that $Labor\ Productivity\ Growth = (Energy/\ Labor) Intensity\ Growth\ + Energy\ Productivity\ Growth.$

[21] Energy productivity growth rate was mostly constant at the global level.

[22] See Semieniuk (2016, 2021); Taylor (2008).

[23] See also Lance et.al (2021) https://www.ineteconomics.org/uploads/general/Taylor-NCC-blog-0219-afternoon-redone.pdf.

[24] We know that carbon intensity of energy is very high for south Africa. This means that even though the energy intensity increases as a result of mitigation efforts (i.e., transitioning to more efficient energy production etc.) will not eliminate emissions completely. In order to do so, South Africa has to switch to renewables.

[25] $\left(\hat{q}[t] - \hat{\xi}[t]\right)$ represents the growth rate of (inverse of energy productivity) which also means that increasing energy productivity cuts into emissions.

Finally, since the consumption, rather than income, is more likely to be the main driver of emissions and different households have different propensity to consume or save to capture emission inequality, workers' (bottom 90 percent of HH) and capitalists' (top 10 percent of HH) emissions are set proportional to total emission by their (weighted) share in GDP (*X[t]*). Therefore, workers' and capitalists' emissions are represented by

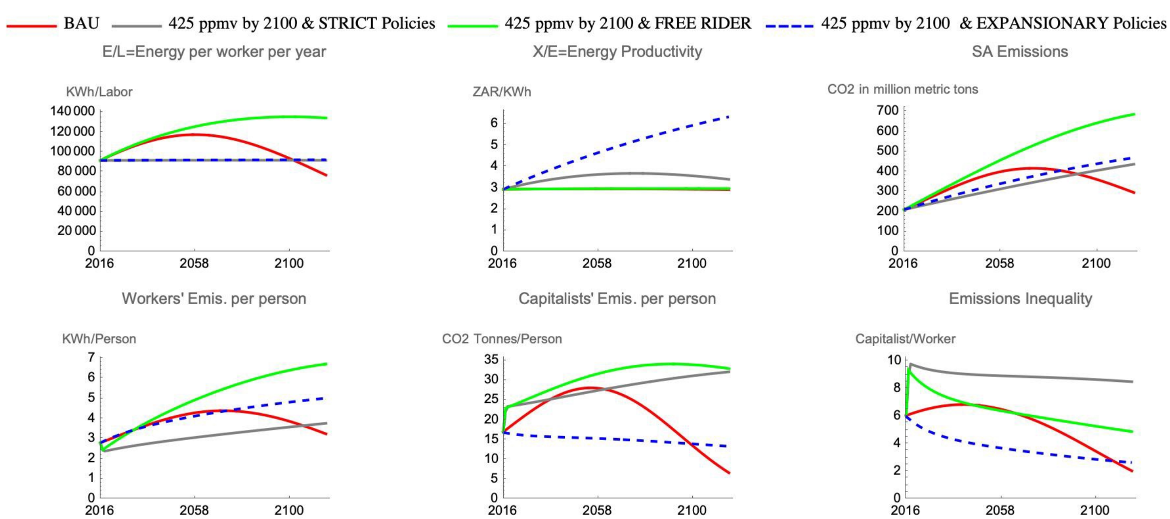
$$Emis_w[t] = Emis[t] * \frac{C_w[t]}{X[t]}$$

$$Emis_P[t] = Emis[t] * \frac{C_p[t]}{X[t]}$$

This relationship, in turn, is used to calculate per capita emissions for each class such that the ratio of $\frac{Capitalists' \ emissions \ per \ capita}{Workers' emissions \ per \ capita}$ provides a simple metric to assess emission inequality between the capitalists and workers[26]. Hence,

$$\frac{Capitalists' \ emissions \ per \ capita}{Workers' emissions \ per \ capita} = \frac{\left(\frac{Emis_c[t]}{Pop_c[t]}\right)}{\left(\frac{Emis_w[t]}{Pop_w[t]}\right)}$$

Figure 8: Energy Use, Energy Productivity, Emissions and Inequality



Source: Authors' calculations.

- In the *BAU (red)* and the *free riding scenarios*, the elasticity of energy use per worker with respect to labor productivity is assumed to be equal to 1 ($v = 1$) as there is no attempt to transform the fossil fuel dependent economic structure into a more efficient green economy. As a result, energy productivity remains constant while energy use per worker changes with labor productivity.

- *In the BAU scenario*, South Africa's carbon emissions increase until 2060 as economic activity and labor productivity rise. During that timeframe, emission inequality also increases since consumption per capitalist rises more than consumption per worker. Subsequently,

[26] Disaggregated Households' Emissions data is retrieved from OXFAM (2015).

economic activity and labor productivity decline sharply, dragging down emissions and emission inequality.

- The situation is more worrisome under *the free riding case* because, as discussed earlier, stronger climate action by the rest of the world generates enough policy space for South Africa to grow and stabilize on a higher level of economic activity without transitioning to a green economy. On the other hand, declining profits—capitalists' main source of income due to higher employment growth (via profit squeeze)–drive down capitalists' consumption, hence emission inequality goes down after a couple of decades.

In the expansionary and stricter policy cases, mitigation policies are assumed to focus on utilizing greener energy sources, hence , meaning that fossil-fuel-dependent energy use per labor remains constant while energy productivity changes with labor productivity. More efficient energy use reduces emissions in both cases while the use of different taxation policies determines the distribution of the emissions within the country. For example, as Figure 8 shows, emission inequality between capitalists and workers shoots up in the stricter policy case because tax policy is regressive—tax increases are the same for both classes. Even though overall emissions are reduced, consumption *per capitalist* remains well above consumption *per worker*, resulting in higher inequality of emissions. *In the expansionary policy case*, on the other hand, both total emissions and emission inequality are reduced with the help of more progressive taxation policies—consumption per worker grows while consumption per capitalist declines due to higher tax increase on capitalists' income.

This simple simulation exercise shows that emission inequality is closely tied to income inequality patterns, which are shaped by policy choices. It is also apparent that although they may utilize carbon energy more efficiently, countries will continue to emit, unless they phase out carbon energy completely, decarbonize electricity generation and prevent residual industrial emissions from getting into atmosphere (Ekins et al., 2022). But what level of emissions will be induced by whom, and who will pay for the cost remain open policy questions.

CONCLUSION

Achieving higher economic activity to support green structural transformation in a more equitable and sustainable way is a demanding task, which necessitates proper coordination between the public and private sectors and the support from regional and international institutions (multilateral development banks, the International Monetary Fund, the World Bank and beyond), particularly in countries that, like South Africa, face challenges related to the green transition on the demand side, the supply side. and the policy side. This includes:

- Coal and coal-dependent products account for South Africa's largest export share;
- It has a large fossil fuel-based energy sector that needs to be replaced by more efficient and greener sources;
- Its output and productivity growths have been slowing down while unemployment has been skyrocketing; and
- It has been experiencing premature deindustrialization and financialization, simultaneously.

But more importantly, South Africa's income inequality is one of the highest in the world. As observed during the COVID-19 crisis and shown in our simulations, the bottom 90 percent of households will be most impacted by the crises and the policies triggered by climate change. To tackle this complex issue, policymakers must first understand how inequality and macroeconomic dynamics affect each other. The concerns about the distributional impacts of macro structural policies should be studied in detail so that green policies can eliminate distortions that may worsen the existing inequalities during the transition. Then, those relationships must be carefully included in growth and development models.

As our model simulations show, for the necessary green structural change, economic activity must be supported by sustainable productivity increases, spurring job creation via increased actual (and potential) output in the economy. However, it should be emphasized that this transformation can exacerbate distributional dynamics easily if the real wage increases of most vulnerable households remain below the productivity increases—the main cause of historically low and declining wage share in many developed and developing countries.

To attain equitable growth, productivity enhancing structural change must be combined with progressive redistribution policies, especially since climate change related downturns will impact sectors which employ the most vulnerable part of the population more severely. For example, as discussed above, the bottom 60 percent of households in South Africa mostly consist of Black Africans—mostly female – who are either unemployed, living on government transfers or employed in low paying, low-skilled agriculture, minerals and construction sectors while the middle class includes people who work in minerals-related heavy industry, trade services and mining sectors, which pay less than the white-male dominated sectors such as utilities, FIRE and business services. Looking at the bright side, manufacturing, trade, construction and utilities also have the potential to create well-paid, high productivity green jobs if they can be restructured and decarbonized successfully. This, however, may not be enough to have a more equal society, unless supported by labor friendly rules and policies. To reach that goal, labor's bargaining power must be strengthened by enforceable work contracts, higher minimum wage and social contracts–i.e., better social security and welfare services. According to the International Labour Organization (ILO) (2018), the green transition will create 16 million extra jobs globally by 2030.

Employment must be more inclusive, meaning that unskilled workers, mostly Black Africans, at the bottom 60 percent of households should be given more opportunities. Climate change and the green transition might reduce the share of women in employment as sectoral transformation will be associated with male dominated industries such as renewables, manufacturing and construction, as was the case during the COVID-19 crisis. Moreover, 52 percent of women are poor, and women's median earnings are 76 percent those of men in South Africa (StatsSA, 2018a, b; FFC, 2021, Chapter 5). Therefore, gender responsive planning, budgeting and policy must be at the center of distributional policies. Women's participation to the green transformation can be supported by sector specific public and private training programs. For example, based on a Green Jobs Programme, supported by the ILO, women in Zambia learnt how to build houses using green technologies and install solar panels (ILO, 2018). Similarly in Egypt, people were taught how to produce biogas that has been used as affordable source of energy and fertilizer, and increased income and crop production.

Additionally, government grants, transfers and unemployment protection programs and progressive taxation tools must be utilized to redistribute income more equally. These programs must be strengthened and made universal. In addition to our simulation examples on progressive taxation in the previous section, the government can take a step further and build a wealth fund to support the green transition by taxing rich households' capital gains. This fund can then be used to support workers' incomes against climate change related risks such as job and income losses, health deterioration and environmental degradation. To illustrate, Poland and Romania provided financial support for people who lost their jobs in the coal industry due to green transition and reskilled them so that they can find new jobs in more environmentally sustainable industries (ILO, 2018).

As our simulations indicate, another constraint that policy makers face is the trade-off between inequality and long-term debt. On the one hand, *stricter fiscal and monetary policies* produce lower external debt at the expense of low economic growth and higher income inequality, which endanger the green structural transformation in the long run. On the other hand, *expansionary mitigation and adaptation policies*, which are supported by progressive taxation and income policies generate more plausible results that are key to greener, sustainable and more equitable economic growth. In this case, long term debt-to-GDP ratio is slightly higher than the stricter policy case, but it is sustainable given the higher long-term GDP and productivity growth. As shown above, public spending on mitigation and adaptation, combined with progressive redistribution, a stable and competitive real exchange rate and a relatively low real interest rate can be instrumental in restructuring the economy and improving its prospects for a greener development. This combination of policies seems to trigger green investments more than any other cases because they result in higher productivity growth, which in turn produces larger output (income). As the increased output is redistributed towards the low-income households (workers) with higher propensity to consume, inequality declines while the aggregate demand goes up by pushing incomes up further. As a result, income inequality can be tamed and unemployment reduced while fiscal space is expanded, supporting long-term debt sustainability, simultaneously.

REFERENCES

Ekins, P., and Drummond, P., and Scamman, D., and Paroussos, L. and Keppo, I., 2022. 1.5C Climate and Energy Scenarios: Impacts on Economic Growth. *Oxford Open Energy*, Vol: 1.

FFC, (2021). Technical Report: Submission for the division of revenue, 2022/23.

Finn, A., and Leibbrandt, M., and Woolard, I., 2009. Income & Expenditure Inequality: Analysis of the NIDS Wave 1 Dataset, National Income Dynamics Study.

Finn, a. and Leibbrandt, M., 2016. The dynamics of poverty in the first four waves of NiDS.

ILO, 2018. World Employment Social Outlook: Greening with Jobs.

International Debt Statistics, World Bank. https://datatopics.worldbank.org/debt/ids/country/ZAF

Jiang, X. and Kahn, A. Haider (2017). Structural Change and Energy Use in China: A SAM Based CGE Analysis. The Chinese Economy, 50:6, 405-424, DOI: 10.1080/10971475.2017.1380021.

Makgetla, N., 2020. Inequality in South Africa: An Overview, TiPS.

Nattrass, N. and Seekings, J., 2015. Should and can labour-surplus, middle-income economies pursue labour-intensive growth? The South African challenge, CSSR Working Paper No. 351, University of Cape Town, March 2015

Omer, O. and Capaldo, J., 2022. The Risks of the Wrong Climate Policy for Developing Countries: Scenarios for South Africa. Working Paper. https://www.bu.edu/gdp/files/2022/03/GEGI_WP_055_FIN.pdf

OXFAM, 2015. Technical Note: Carbon Emissions and Income Inequality.

WID Report, 2017.

Ravallion, M. and Heil, M. and Jalan, J., 2000. Carbon Emissions and Income Inequality, Oxford Economic Papers, Vol. 52, No. 4, pp. 651-669.

BU Global Development Policy Center

Boston University
53 Bay State Road
Boston, MA 02215

gdp@bu.edu
@GDP_Center
bu.edu/gdp

The Global Economic Governance Initiative (GEGI) is a research inititiative at Boston University Global Development Policy Center. The GDP Center is a University wide center in partnership with the Frederick S. Pardee School for Global Studies. The Center's mission is to advance policy-oriented research for financial stability, human wellbeing, and environmental sustainability.

www.bu.edu/gdp

Rezai, A., and Taylor, L., and Foley, D. (2018). Economic Growth, Income Distribution, and Climate Change. Ecological Economics, Vol: 146, pp:164-172.

Semieniuk, G. (2016). Fossil Energy in Economic Growth: A Study of the Energy Direction of Technical Change, 1950-2012. Working Paper, SPRU Working Paper Series.

Semieniuk, G. and Taylor, L. and Rezai, A. and Foley D. K. (2021). Plausible energy demand patterns in a growing global economy with climate policy. Natura Climate Change, vol:11, pp: 313-318.

Schotte, S., and Zizzamia, R. and Leibbrandt, M., 2022. Snakes and ladders and loaded dice: Poverty dynamics and inequality in South Africa between 2008 and 2017, South African Journal of Economics, DOI: 10.1111/saje.12308.

Stats SA. 2018a. Quarterly Labour Force Survey. Pretoria: Stats SA.

Stats SA. 2018b. *Men, women and children: Findings of the Living Conditions Survey 2014/15*. Pretoria: Stats SA.

Taylor, L. (1982). Back to Basics: Theory for the Rhetoric in North-South Round. World Development, Vol:10, No:4, pp:327-335.

Taylor, L., and Omer, O. and Rezai, A. (2015). Wealth Concentration, In- come Distribution, and Alternatives for the USA. INET Working Paper.

The World Bank, 2022. Inequality in Southern Africa: An Assessment of the Southern African Customs Union.

Vimal, V. and Daniels, A., R., J., 2021. Labour market dynamics in South Africa at the onset of the Covid-19 Pandemic, South African Journal of Economics Vol. 89:1.

von Arnim, R., & Rada, C., 2011. Labour Productivity and Energy Use in a Three-Sector Model: An Application to Egypt. *Development and Change*, 42(6), 1323–1348.